

IMPACT OF TEMPERATURE INCREASE ON POWDERY MILDEW IN MELON

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ABSTRACT

The increase in greenhouse gases (GHG) has caused an increase in atmospheric temperature. It is known that temperature is determinant for the occurrence of plant diseases. In this context, the objective of this study was to evaluate the influence of temperature on powdery mildew in detached leaves of different melon cultivars. Nine melon cultivars were used: Araguaia, Awton, Eldorado, Gladial, Gold, Hibix, Natal, Juazeiro and Sancho. Two experiments were carried out with detached leaves in incubators with control of temperature and photoperiod (12/12h). The first experiment was conducted to determine the optimum temperature (15, 20, 25, 30, 35 and 40 °C) for the development of the disease and, from this temperature, increments of 1.7, 2.6, 3.1 and 5 °C, corresponding to the IPCC scenarios, were evaluated. The leaves were inoculated with a suspension of conidia of *Oidium* sp., placed on trays and kept in incubators. It was found that air temperature influences both the incubation period and severity of the disease. The optimum range for the development of melon mildew was 20-25 °C, and the increase in air temperature reduces the severity of the disease and, from 30 °C, there is no appearance of symptoms. The incubation period of melon powdery mildew increases at temperatures of 15 °C and above 27.6 °C. Melon cultivars show different responses to temperature increases. However, all cultivars were susceptible to powdery mildew, with high severity at temperatures favorable to the development of the pathogen.

Keywords: *Podosphaera xanthii*; *Oidium* sp.; Climatic Changes; *Cucumis melo*.

RESUMO

Impacto do aumento da temperatura sobre o oídio em meloeiro. O aumento dos Gases de Efeito Estufa (GEEs) tem provocado aumento da temperatura atmosférica. Sabe-se que a temperatura é determinante na ocorrência de doenças de plantas. Nesse sentido, o objetivo com este estudo foi avaliar a influência da temperatura sobre o oídio em folhas destacadas de diferentes cultivares de meloeiro. Foram utilizadas nove cultivares de meloeiro Araguaia, Awton, Eldorado, Gladial, Gold, Hibix, Natal, Juazeiro e Sancho. Foram realizados dois experimentos com folhas destacadas em incubadoras com controle de temperatura e fotoperíodo (12/12h). O primeiro experimento foi conduzido para determinar a temperatura ótima (15, 20, 25, 30, 35 e 40 °C) para o desenvolvimento da doença e, a partir dessa temperatura, avaliou-se o aumento de 1,7; 2,6; 3,1 e 5 °C, correspondente aos cenários do IPCC. As folhas foram inoculadas com suspensão de conídios de *Oidium* sp., acondicionadas em bandejas e mantidas nas incubadoras. Verificou-se que a temperatura do ar influencia tanto o período de incubação quanto a severidade da doença. A faixa ótima para o desenvolvimento do oídio do meloeiro foi de 20-25 °C, sendo que o aumento da temperatura do ar reduz a severidade da doença e, a partir de 30 °C não há aparecimento dos sintomas. O período de incubação

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do oídio do meloeiro aumenta em temperaturas de 15 °C e acima de 27,6 °C. As cultivares de meloeiro apresentam respostas diferenciadas aos aumentos de temperatura. Entretanto, todas as cultivares foram suscetíveis ao oídio, com alta severidade em temperaturas favoráveis ao desenvolvimento do patógeno.

Palavras-chave: *Podosphaera xanthii*; *Oidium* sp.; Mudanças Climáticas; *Cucumis melo*.

INTRODUCTION

The Northeast region is responsible for 95% of melon (*Cucumis melo* L.) production in Brazil, with a total of 514,276 tons (IBGE, 2017). However, like all other agricultural activities, its production is directly linked to climatic elements and the occurrence of phytosanitary problems.

Temperature is a determining climatic element in the occurrence of plant diseases, playing an important role in the different stages of the life cycle of pathogens (Bettiol et al., 2017). This climatic element can increase or decrease infection (Debela and Tola, 2018), also acting in the colonization, sporulation and dispersion of pathogens (Elad and Pertot, 2014; Das et al., 2016).

According to the Intergovernmental Panel on Climate Change (STOKER et al., 2013), there may be changes in average air temperature, caused by an increase in the concentration of greenhouse gases (GHG). The estimated increments are 1.7 °C and 4.8 °C in the Representative Concentration Pathways (RCP) 2.6 and 8.5, respectively, until 2100. This can impact the occurrence of phytosanitary problems, increasing or decreasing the severity of plant diseases (Nazir et al., 2018). This occurs because changes in climate can result in changes in the interaction between the components environment, host and pathogen, which make up the disease triangle. These changes can modify the geographical and temporal distribution of pathogens, altering the progress of epidemics in different growing regions (Bettiol et al., 2017).

Therefore, temperature will play an important role in the quantification of the monocyclic components of the different pathosystems, especially the incubation period. Knowledge on how temperature influences this component may contribute to the determination of management strategies (Marcuzzo and Souza, 2018) since, in order to reduce the development of an epidemic, one can reduce the initial amount of the inoculum, delaying its onset.

Melon powdery mildew, caused by the fungus *Podosphaera xanthii* Braun & Shishkoff (anamorphic *Oidium* sp.), is one of the main leaf diseases of cucurbits (McGrath, 2017). Its infection and development are associated with temperatures between 20 °C and 25 °C (Rabelo, 2017). The Brazilian semi-arid region has favorable temperature for the occurrence of this pathogen virtually all year round, with greater intensity in the months with milder temperatures. In a scenario of climate change there may be a change in the geographical and temporal distribution of this disease in the region, as has already been verified for other mildew species in future climatic scenarios (Hamada et al., 2015).

Thus, the objective of this study was to evaluate the influence of temperature on powdery mildew in detached leaves of different melon cultivars.

MATERIAL AND METHODS

The experiment was conducted in BOD (Biochemical Oxygen Demand) incubators, with temperature and photoperiod (12/12h) control, at Embrapa Semi-arid, in Petrolina-PE. Two experiments were carried out, the first to determine the optimum temperature for the development of melon powdery mildew and, from this temperature, the second to evaluate the effect of the temperature increase on the severity of the disease, corresponding to the scenario of the IPCC.

Both experiments were conducted using detached leaves of nine melon cultivars, seven of the yellow type: Araguaia, Awton, Eldorado, Gladial, Gold, Hibix and Natal, and two of the *Piel de Sapo* type: Juazeiro and Sancho. Detached leaves of plants with approximately 60 days were used, which were cut at the base of the petiole using professional scissors, followed by thinning and cleaning. Then, the petiole was wrapped in cotton soaked in distilled water to prevent dehydration.

For inoculation, the leaves were sprayed with a suspension of conidia of *Oidium* sp. (teleomorph *Podosphaera xanthii*), at the concentration of 10^5 conidia mL⁻¹ of water with 0.01% Tween 20, and placed in polyethylene trays containing paper towel moistened with distilled water. Then, the trays were covered with PVC film to promote a humid chamber and placed in BOD incubators. To determine the optimum temperature for the development of the disease, the trays containing four leaves inoculated per cultivar were kept at temperatures of 15, 20, 25, 30, 35 and 40 °C.

The inoculum was obtained from conidia of melon leaves with natural infection, collected in Petrolina-PE, Brazil. For the multiplication and maintenance of the inoculum, healthy seedlings of the melon cultivar Sancho were inoculated and kept in a greenhouse.

To evaluate the effect of temperature increase on powdery mildew severity, the temperature leading to greatest development of the disease in the previous experiment (25 °C) and the same methodology described above were used. In addition to the temperature of 25 °C, temperatures of 26.7, 27.6, 28.1 and 30 °C were also evaluated, corresponding to the increases of 1.7, 2.6, 3.1 and 5 °C according to future climatic scenarios (STOKER et al., 2013).

In the experiments, disease severity was periodically evaluated, adapting the diagrammatic scale developed by Buffara et al. (2014), with intervals of 1, 5, 12, 25, 50, 75 and 100% of the sick leaf area. The incubation period, determined by the number of days between inoculation and the appearance of mycelial mass, was also evaluated.

The experimental design used was completely randomized in a 6 (temperatures) x 9 (cultivars) factorial scheme and experimental plot of four detached leaves by treatment. Severity values were used to calculate the area under the disease severity progress curve (AUDSPC), which is obtained using the formula $AUDSPC = \sum (y_i + y_{i+1}) / 2 \times dt_i$, where $y_i + y_{i+1}$ are the values observed in two consecutive evaluations and the dt_i is the interval between the evaluations (Shaner and Finney, 1977).

The data were subjected to analysis of variance, and the means were compared by the Scott-Knott test, using the Sisvar software (Ferreira, 2011).

RESULTS AND DISCUSSION

In the experiment that determined the optimum temperature for the development of the disease, the analysis of variance showed significant F values for cultivars, temperature and for the interaction between these two factors (Table 1). The highest levels of AUDSPC were observed in detached leaves maintained at temperatures of 20 °C (448.1) and 25 °C (458.7). Leaves exposed to temperatures of 30 °C, 35 °C and 40 °C showed no symptoms of the disease (Table 1). For leaves maintained at 15 °C, disease progress was slower, with lower severity for all cultivars (Table 1).

When disease severity in cultivars was evaluated separately, the lowest disease intensity was found in leaves of the cultivars Awton, Gold and Gladial, with lower values of AUDSPC. Nevertheless, the cultivars were susceptible to powdery mildew and, despite the statistical difference (Table 1), the levels of severity in the leaves were high, above 60% at 25 °C (Figures 1 and 2).

A significant interaction between temperature and cultivars was also observed (Table 1). At 25 °C, the cultivars with the highest disease severity were Eldorado, Gold, Hibix and Sancho, not differing from each other, but differing from the others (Table 1). For the temperature of 15 °C, the lowest value of AUDSPC was observed for the cultivar Gold.

Table 1. Area under the disease severity progress curve (AUDSPC) for powdery mildew in detached leaves of nine melon cultivars, under different temperatures

Cultivars	Temperatures (°C)						Means
	15	20	25	30	35	40	
Araguaia	185.5db	470.0aa	432.5ba	0ac	0ac	0ac	181.3a
Awton	113.5eb	447.5ba	448.0ba	0ac	0ac	0ac	168.2b
Eldorado	270.2ab	475.5aa	476.2aa	0ac	0ac	0ac	203.7a
Gladial	154.0db	416.2ca	447.7ba	0ac	0ac	0ac	169.7b
Gold	68.0fc	373.5db	469.0aa	0ad	0ad	0ad	151.8b
Hibix	223.0cc	430.5cb	492.5aa	0ad	0ad	0ad	191.0a
Juazeiro	241.0bb	445.2ba	450.0ba	0ac	0ac	0ac	189.4a
Natal	151.0dc	497.5aa	448.5bb	0ad	0ad	0ad	182.9a
Sancho	224.0cb	476.5aa	464.2aa	0ac	0ac	0ac	194.1a
Means	181.1b	448.1a	458.7a	0c	0c	0c	

Means followed by the same uppercase letter in the column and lowercase letter in the row, do not differ from each other by the Scott-Knott test at 5% probability level.

Through the disease progress curve, it can be observed, in general, that at the most favorable temperatures (20 °C and 25 °C), the incubation period varied from four to seven days (Figure 1). The shortest incubation period was four days for the cultivars Awton, Natal and Sancho at 20 °C and for the cultivars Eldorado, Gladial, Hibix, Juazeiro, Natal and Sancho kept at 25 °C. However, for the leaves kept at 15 °C, this period was equal to seven days, except for the Gladial cultivar, which had an incubation period of ten days.

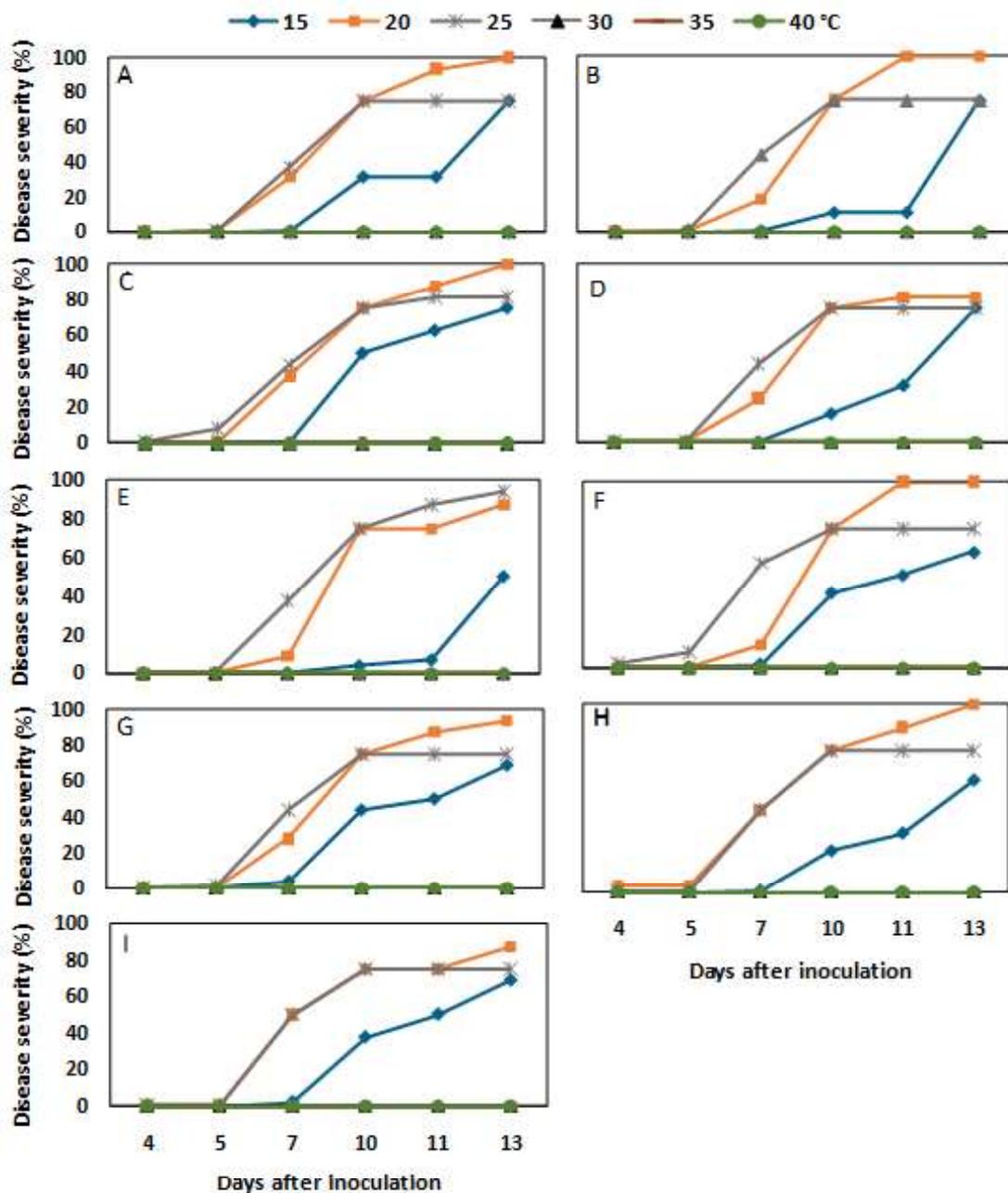


Figure 1. Powdery mildew severity progress curve in detached leaves of melon cultivars maintained at temperatures of 15, 20, 25, 30, 35 and 40 °C. Cultivars: Araguaia (A), Awton (B), Eldorado (C), Gladial (D), Gold (E), Hibix (F), Juazeiro (G), Natal (H) and Sancho (I).

Temperature is one of the important climatic elements for the infection of the various pathogens, exerting direct influence on the reduction of the disease progress rate (Cerkauskas and Brown, 2015; Cohen et al., 2017). For most pathogens, temperature can determine the speed and extent of infection (Campbell and Madden, 1990). In a study carried out with tomato powdery mildew (*Oidium neolycopersici* Kiss), the optimum temperature for the development of the disease was 22 °C (Cerkauskas and Brown, 2015). For rosebush powdery mildew (*Sphaerotheca pannosa* Wallroth), the average temperature was between 19 and 24.6 °C (Kumar and Chandel, 2018). In a study conducted with wheat, the optimum temperature for infection of the fungus *Blumeria graminis* DC. was 23.6 °C (Mehta et al., 2018). For mango powdery mildew (*Oidim mangiferae* Berthet), the highest levels of severity were related to the temperature of 30 °C

(Pérez-Rodríguez et al., 2017). This shows the diversity of the optimum temperature range for the different plant-host relationships, with changes in the ranges of different crops and mildew genera.

In this study it was possible to observe that the temperature of 15 °C delayed the incubation period. The incubation period is considered an important component for the epidemiology of the disease and may explain the delay in the onset of an epidemic. Incubation periods of different cultivars can contribute to plant breeding programs, being one of the monocyclic parameters that determine the resistance of a cultivar (Klosowski et al., 2015).

In the experiment for temperature increases, corresponding to the IPCC scenarios, a significant difference was also observed for the effects of cultivars, temperature and cultivars x temperatures interaction on the severity of melon powdery mildew.

In general, there was a reduction in disease severity with the increase in temperature (Table 2). The highest severity was found in leaves maintained at 25 °C, with an average of 243.9, with reduction at 28.1 °C, with an average of 27.8, and no symptoms of mildew in leaves maintained at 30 °C. And the lowest values of AUDSPC were verified for the cultivars Gladial, Gold and Natal (Table 2). Temperature is one of the important climatic elements for the infection of the various pathogens, exerting direct influence on the reduction of the disease progress rate (Cerkauskas and Brown, 2015; Cohen et al., 2017). For most pathogens, temperature can determine the speed and extent of infection (Campbell and Madden, 1990). In a study carried out with tomato powdery mildew (*Oidium neolycopersici* Kiss), the optimum temperature for the development of the disease was 22 °C (Cerkauskas and Brown, 2015). For rosebush powdery mildew (*Sphaerotheca pannosa* Wallroth), the average temperature was between 19 and 24.6 °C (Kumar and Chandel, 2018). In a study conducted with wheat, the optimum temperature for infection of the fungus *Blumeria graminis* DC. was 23.6 °C (Mehta et al., 2018). For mango powdery mildew (*Oidium mangiferae* Berthet), the highest levels of severity were related to the temperature of 30 °C (Pérez-Rodríguez et al., 2017). This shows the diversity of the optimum temperature range for the different plant-host relationships, with changes in the ranges of different crops and mildew genera.

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Table 2. Area under the disease severity progress curve (AUDSPC) for powdery mildew in detached leaves of nine melon cultivars, under different temperatures corresponding to the increases of 1.7, 2.6, 3.1 and 5 °C according to the future climatic scenarios (STOKER et al., 2013).

Cultivars	Temperatures (°C)					Means
	25	26.7	27.6	28.1	30	
Araguaia	201.6ca	201.8ba	59.0ab	29.8bb	0ac	98.5b
Awton	340.7aa	262.0ab	88.1ac	71.6ac	0ad	152.5a
Eldorado	255.1ba	213.7ba	79.0ab	16.7bc	0ad	112.9b
Gladial	205.3ca	79.2db	31.5bc	1.7bc	0ad	63.6c
Gold	179.0ca	133.0ca	11.2bb	3.6bb	0ac	65.4c
Hibix	281.8ba	140.7cb	79.8ac	53.2ad	0ae	111.1b
Juazeiro	214.2ca	197.5ba	71.8ab	0.0bc	0ad	96.7b
Natal	247.0ba	102.8db	45.3bc	26.2bc	0ad	84.3c
Sancho	269.6ba	150.8cb	96.1ac	11.7bd	0ae	105.7b
Means	243.9a	143.5b	79.6c	27.8d	0e	

Means followed by the same uppercase letter in the column and lowercase letter in the row do not differ from each other by the Scott-Knott test at 5% probability level.

By analyzing the disease progress curve, it was found that the incubation period was equal to five days for all cultivars maintained at 25 °C. In leaves maintained at 27.6 °C and 28.1 °C, it took six to seven days for the onset of the first symptoms of the disease (Figure 2). The disease progress curves show how the epidemic acts on the plant, expanding at high rates when temperatures are favorable to its development. With these data it is possible to visualize which temperatures may favor the occurrence of a given disease (Bergamin Filho and Amorim, 2018).

There was also a significant difference for interaction between temperature and cultivars, which showed different responses to the temperature increases (Table 2). In general, it was verified that the use of detached leaves made it possible, in a practical way, to verify the response of the different cultivars, confirming that they did not have tolerance to powdery mildew at the different temperatures studied, except at 28.1 °C for Juazeiro and 30 °C for all cultivars, which did not show symptoms of the disease. Studies evaluating the severity of the disease in different cultivars will be strategic for the adoption of adaptation measures. However, it is understood that the pathogen-host-environment interaction is complex, being considered a challenge for agricultural research in the face of climate change (Juroszek et al., 2020). At the same time that the increase in temperature can promote genetic variability for the pathogen, enabling its adaptation to a new environment, it alters the resistance/susceptibility mechanisms of the host plant (Gautam et al., 2013).

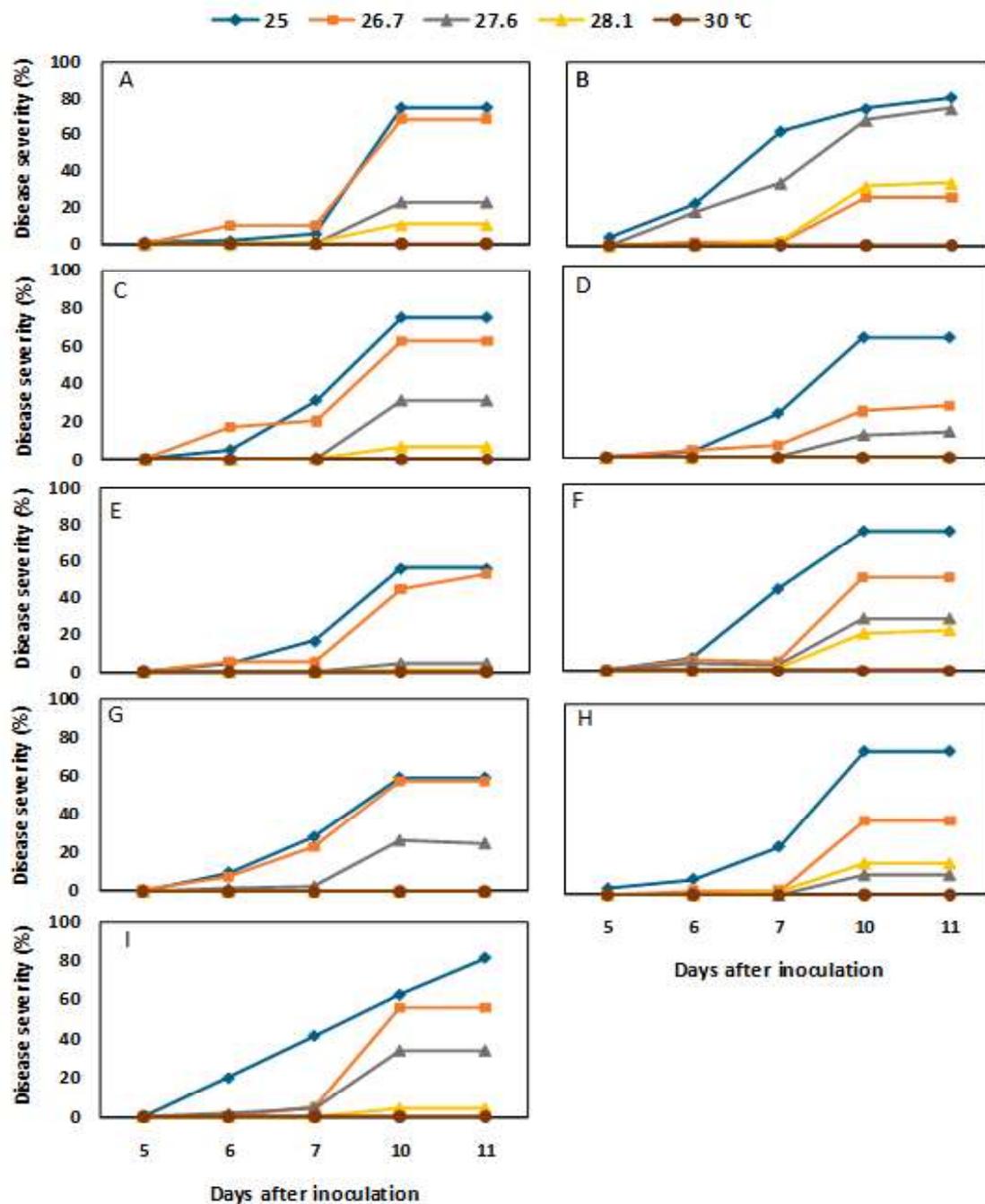


Figure 2. Powdery mildew severity progress curve in detached leaves of melon kept at temperatures of 25, 26.7, 27.6, 28.1 and 30 °C. Cultivars: Araguaia (A), Awton (B), Eldorado (C), Gladial (D), Gold (E), Hibix (F), Juazeiro (G), Natal (H) and Sancho (I).

There was a reduction in the severity of melon powdery mildew with the increase in temperature. For the grape powdery mildew, Caffarra et al. (2012) verified a reduction in the disease severity due to the increase in air temperature. However, in Brazil, the maps of geographic distribution of grape powdery mildew showed an increase in the area favorable to its incidence (Hamada et al., 2015). It is known that climatic elements can act on the severity of the disease and its geographical and temporal distribution. In this context, any change in temperature can cause change in the intensity of the disease or in its rate of development. Thus, prospective studies evaluating the impacts of climate change on different pathosystems are strategic and can contribute to the development of adaptation measures (Bettiol et al., 2017).

CONCLUSIONS

The optimum temperature range for melon powdery mildew development was 20-25 °C. In a temperature increase scenario, there will be a reduction in the severity of the disease.

The incubation period of melon powdery mildew increases at temperatures of 15 °C and above 27.6 °C. From 30 °C, there is no appearance of symptoms of the disease. And the melon cultivars show different responses to air temperature increases, with severity above 60% in the optimum temperature range, highlighting their high susceptibility.

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